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EVALUATION OF POLYPROPYLENE AND POLYETHYLENE CUSHION WRAP MATER--ETC(U)
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EVALUATION OF POLYPROPYLENE AND POLYETHYLENE CUSHION WRAP MATERIALS

HQ AFALD/PTP
AIR FORCE PACKAGING EVALUATION AGENCY
Wright-Patterson AFB OH 45433

April 1977

NOTICE

ABSTRACT

The objective of this study was to evaluate the static and dynamic cushioning properties of polyethylene wrap material in relation to polypropylene wrap material and to determine the relative cost effectiveness of the two materials in package designs.

Peak acceleration (Gs) versus Static Stress curves and "Creep" characteristics were developed for both materials. Using these data and a mathematical model, a cost analysis was accomplished.

The results showed that no cost savings could be realized by substituting polyethylene for polypropylene in existing pack designs. However, polyethylene should be considered as an alternative to polypropylene in new pack designs when item fragility and static bearing stress considerations result in equivalent material costs.

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INTRODUCTION

The periodic development of new packaging wrap materials requires continuing evaluation to determine the most cost effective materials for Air Force and Department of Defense applications. This study reports on the comparative packaging properties of polypropylene and polyethylene foam wrap materials.

OBJECTIVE

The purpose of this study was to evaluate the static and dynamic cushioning properties of polyethylene wrap material in relation to polypropylene wrap material and to determine the relative cost effectiveness of the two materials in package designs.

MATERIALS

The two types of wrap materials evaluated are used for cushioning and surface protection of items. Both are similar in appearance and can be obtained in various thicknesses ranging from approximately 1/16" to 1/4". The polypropylene evaluated had a density of 0.63 lb/ft^3 and the polyethylene, 1.0 - 1.3 lb/ft^3.

The test data presented for the polypropylene was previously developed by this Agency in a similar comparative study on other types of wrap materials. The updated cost figures for the material was used in conjunction with the previous test data for this comparison.

INSTRUMENTATION AND TEST EQUIPMENT

A "Gaynes" drop tester, Model 125 DTP, was used for conducting the free-fall drop tests. Measurements were recorded using the following instrumentation:

a. Three "Endevco" crystal accelerometers, Model 2233E.

b. Three "Endevco" charge amplifiers, Model 2614C.

c. "Endevco" Model 2622C power supply.

d. "Tektronix", type 564B, four trace storage oscilloscope.

TEST PROCEDURES

Two types of tests were conducted:

a. Drop tests to establish Peak "G" versus Static Stress curves for determination of dynamic cushioning properties.

b. Creep tests to determine "set" properties under static loads.

Drop Test

The drop tests employed to establish the Peak "G" versus Static Stress curves were conducted on the "Gaynes" drop tester. In this test a fiberboard container was used to contain the sheets of material being tested. The fiberboard container was constructed of V3c single wall fiberboard which had been pre-compressed to remove most of the cushioning effects of the corrugated media. The inside dimensions of the container were 8-3/8" x 8-3/8" x 8" high.

Two, three, four, or five sheets of the materials to be tested were placed in the fiberboard container. The materials were cut to 8" x 8" squares. Various loads were placed on top of the material to provide the desired static stress levels.

The load was constructed of an aluminum base plate with dimensions 7-3/4" x 7-3/4" x 3/4". This aluminum plate provided the lowest static stress point. To the top of this aluminum plate was mounted additional pieces of aluminum, steel, and lead to provide the various static stress values required. These pieces were fastened to the aluminum base plate by means of screws, nuts, and lock washers. A V3c fiberboard "guide" sleeve, five inches in height, was taped to the perimeter of the base plate. This sleeve of fiberboard was used to help prevent the scrapping of the side-walls of the external container when the aluminum base plate rebounded after impact.

Three "Endevco" accelerometers were mounted triaxially at the center of the aluminum base plate by means of screws. The leads from the accelerometers were connected to three "Endevco" charge amplifiers which in turn were connected to three separate channels of a "Tektronix" storage oscilloscope.

The fiberboard container with the test samples and the required load was positioned on the drop tester so as to produce a flat face impact from a height of 24 inches. The three accelerometer outputs were displayed on the oscilloscope and the impact amplitudes

recorded in terms of peak acceleration (G's). Five drops were made on each set of test material. Three sets of material were evaluated at each static stress load. The first drop test readings for each set of materials were ignored and the other four drops were averaged to obtain one average resultant for each of the three sets of material. The three resultant values were averaged to produce one peak G value for the static stress in question.

Creep Test

Creep tests were conducted on each material in accordance with Federal Specification PPP-C-795A, "Cushioning Material, Flexible, Cellular, Plastic Film for Packaging Applications." In accordance with the specification requirements, the materials were conditioned for 24 hours at 70°F to 76°F before testing.

The material was cut into 5" x 5" samples and stacked approximately one inch high. The material was stacked on a piece of glass, 5-1/2" x 5-1/2" and approximately 1/8" thick. The sheets of material were carefully interwoven with sheets of non-coated, virgin kraft fiberboard with dimensions 5-1/2" x 5-1/2" x 0.026" thick. On top of the material was placed a second piece of glass with the same dimensions as the first piece. Small lead weights were placed on top of three such arrangements to obtain the percentage creep for the 0.1 psi static stress load. After a period of one hour, a measurement was made of the height above the table of the four corners of the top piece of glass. The four measurements were averaged and then the thickness of the two pieces of glass plus the thickness of the sheets of kraft paper were subtracted. This gave the "initial thickness under load." After five days (120 hours) the same measurements were repeated. This gave the "final thickness." The amount of creep was determined by subracting the final thickness from the initial thickness and dividing this difference by the initial thickness. The value obtained was multiplied by a factor of 100 to express creep as a percentage.

To obtain the amount of creep at 0.5 and 1.0 psi, the same procedure of preparing the material and apparatus as described above was used, except that the arrangements were placed in a fixture similar to the one shown in Figure 1 of Method 2013, Federal Test Method Standard No. 101B. This was done to prevent the possibility of the heavier loads from falling off the test samples. The test fixture includes an inner container for holding the necessary weights. After loading the inner container, it was gently lowered onto the top piece of glass of the test sample arrangement. Measure-

ments and calculations of creep were accomplished as described above. The three separate creep test results were averaged to give a resultant value of creep for each static stress load evaluated.

RESULTS

Peak Acceleration versus Static Stress curves developed from the drop test results are presented in Figure 1 through 4. By examining these curves, a comparison can be made between the protection afforded by equivalent thicknesses of polyethylene and polypropylene foam.

Figures 1 and 2 show the drop test results for the 1/8" and 1/4" thick polypropylene material.

Figures 3 and 4 show the drop test results for the 1/8" and 1/4" thick polyethylene material.

Figure 5 presents graphically the creep characteristics of the polypropylene and polyethylene wrap materials. The data points used in constructing the graphs are presented in Table I.

DISCUSSION

General

A minimum of 3 ply of 1/8" and 2 ply of 1/4" was used in evaluating polypropylene and polyethylene materials in order to eliminate data that may have considerable variation due to the load "bottoming out".

Cost Analysis

As can be seen from the Peak "G" versus Static Stress curves in Figures 1 through 4, equivalent thicknesses of different materials produce different peak "G" values. These peak "G" values also vary with the amount of static stress applied to the material. In order to analyze the most cost effective material to use, one can determine the amount and cost of each material required to protect a given weight and size item at a specified "fragility" level. The range of static stress values considered in this analysis varied from 0.08 to 0.42 psi.

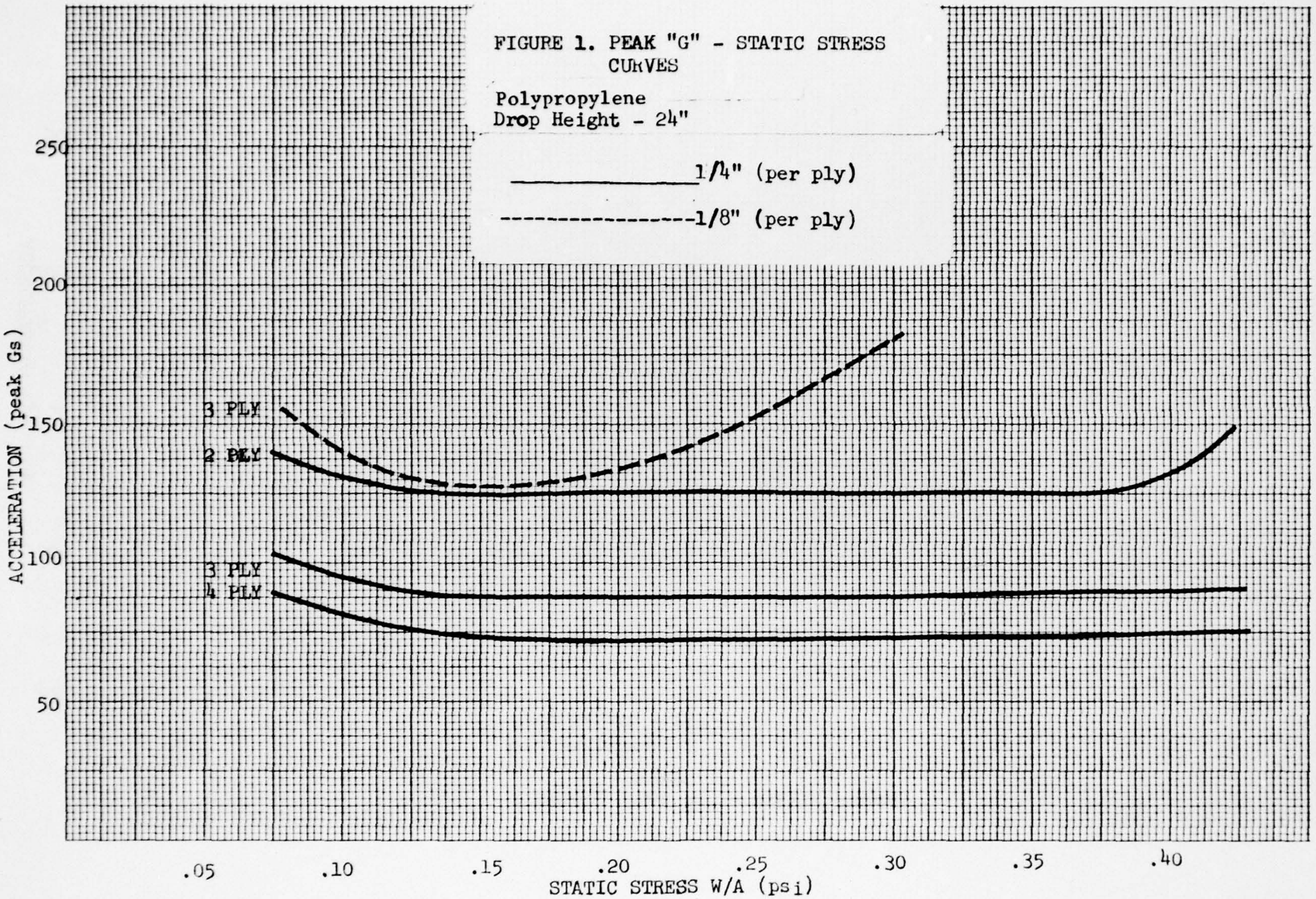

FIGURE 1. PEAK "G" - STATIC STRESS CURVES

Polypropylene
Drop Height - 24"

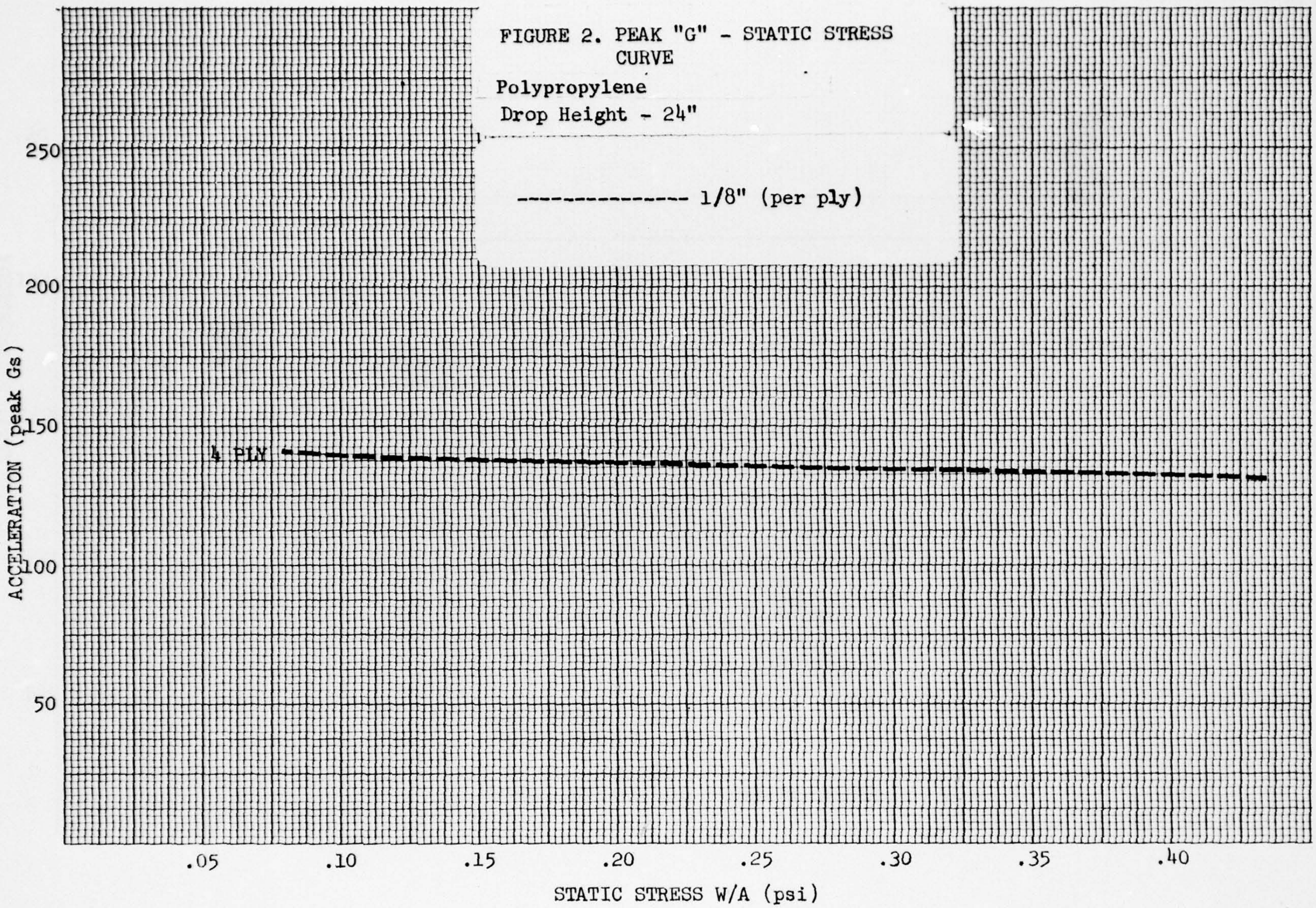

FIGURE 2. PEAK "G" - STATIC STRESS CURVE

Polypropylene

Drop Height - 24"

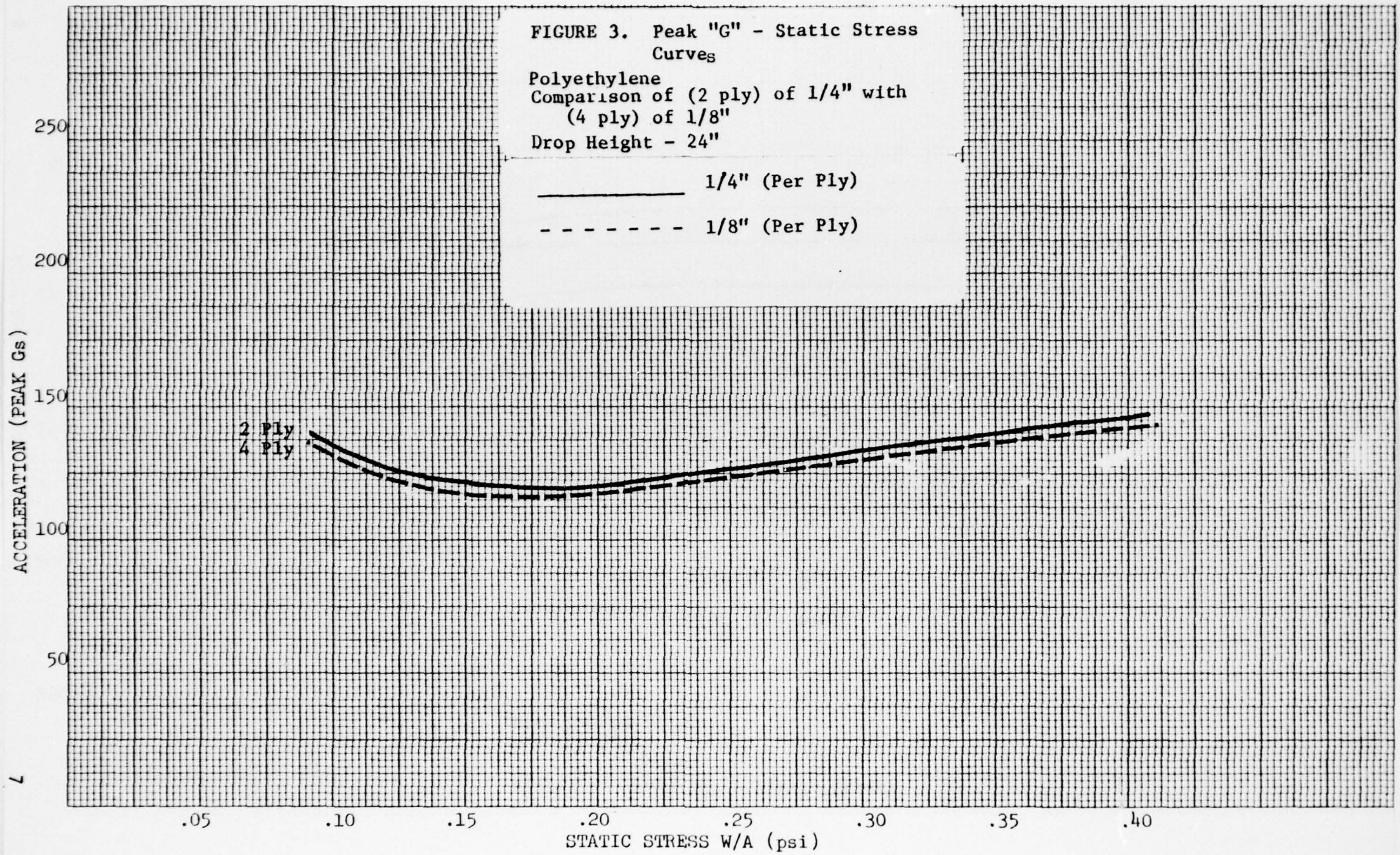

FIGURE 3. Peak "G" - Static Stress Curves
Polyethylene
Comparison of (2 ply) of 1/4" with (4 ply) of 1/8"
Drop Height - 24"
1/4" (Per Ply)
1/8" (Per Ply)
2 Ply
4 Ply
250
200
150
100
50
ACCELERATION (PEAK Gs)
.05
.10
.15
.20
.25
.30
.35
.40
STATIC STRESS W/A (psi)

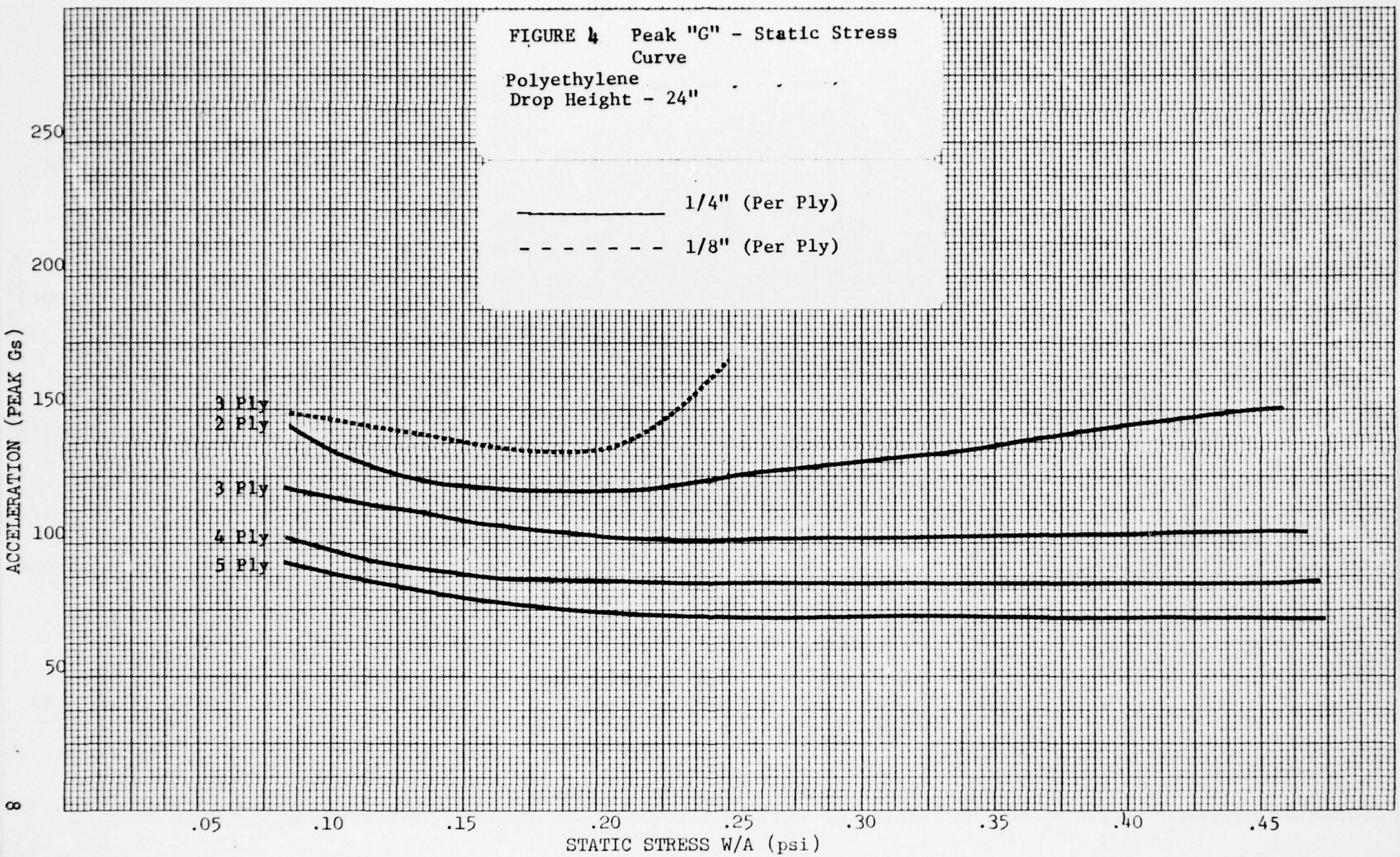

FIGURE 4 Peak "G" - Static Stress Curve
Polyethylene
Drop Height - 24"

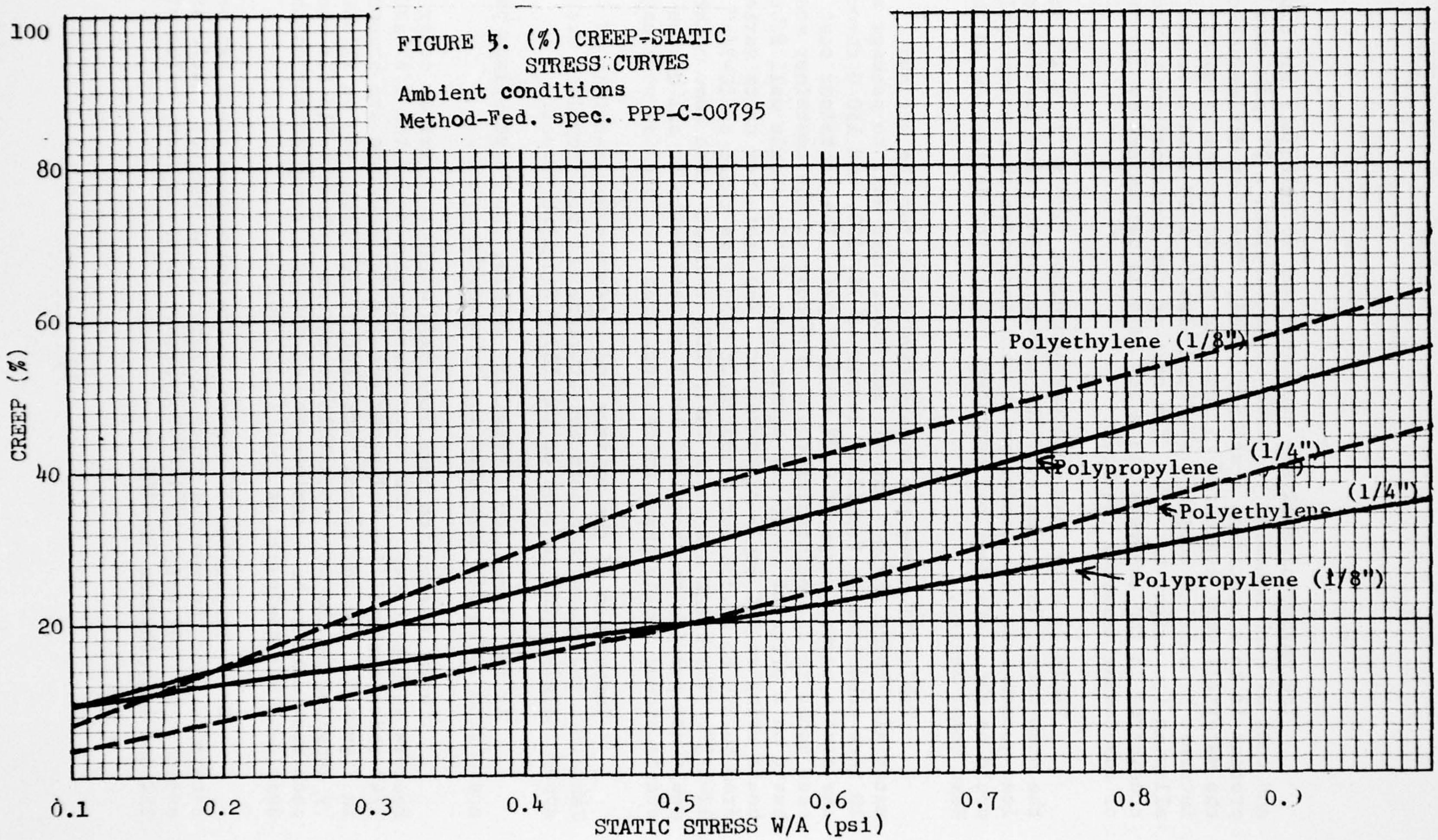

FIGURE 5. (%) CREEP-STATIC STRESS CURVES
Ambient conditions
Method-Fed. spec. PPP-C-00795

The method of analysis used here was to calculate the amount and cost of each material required to encapsulate a 10 inch cube and protect it to a specified fragility level. The cost difference of the materials were evaluated through the static stress range of interest by holding constant the item size to a 10 inch cube and allowing its weight to vary. The cost of the container must also be considered in the analysis since its size is determined by the amount of cushioning material required.

Table II shows the cost per boardfoot (12" x 12" x 1") of the wrap materials evaluated. The maximum order price implies car-load quantities. The vendor price data indicates that polypropylene would be about one cent per boardfoot higher for deliveries to the West Coast States.

Table III shows the comparative costs for the various materials, using maximum and minimum order cost data to package a 10 inch cube item to fragility levels of 75, 100, and 150 G through the static stress range of 0.08 to 0.42 psi. The container cost has been added to the cushioning cost. The cost of the container was based on a price of $0.06 per square foot of V3c single wall fiber-board using an RSC style of container. The container costs varied from $0.399 to $0.536 for a container cube size range of 10-3/4" to 12-1/2". The blank spaces in Table III, indicate that some materials would not provide the required level of protection at all of the static stress levels shown unless more than 4 or 5 plies were used.

Inspection of the maximum and minimum order sections of Table III indicates that both polyethylene and polypropylene are approximately equal in cost at the 150 G fragility level.

At the 75 and 100 G fragility levels, the Polyethylene pack costs from 20 to 24% more than the Polypropylene pack.

These observation have been made without regard to other factors such as creep. The creep characteristics of the 1/8" and 1/4" thick material for Polypropylene and Polyethylene are presented in Figure 5. The additional pack cost due to creep can be illustrated by considering the worst possible condition. Since Table III shows pack cost data to be a maximum at .42 psi, the creep effect on the cost data was evaluated at that stress point.

By an inspection of Figure 5, the percentage creep can be determined for the various types of material at various static stress points. At 0.42 psi, the 1/4" Polypropylene has a creep value of 25% and Polyethylene has 16%.

TABLE I

CREEP (%)

STATIC STRESS (psi)	POLYPROPYLENE		POLYETHYLENE	
	(1/8")	(1/4")	(1/8")	(1/4")
0.1	9.78	9.64	7.10	3.88
0.5	19.10	29.60	37.20	19.30
1.0	36.00	56.00	63.00	44.80

TABLE II

COST DATA

MATERIAL	THICKNESS/PLY	$COST/BDFT MAX ORDER	MIN ORDER
Polypropylene	0.125"	0.135	0.193
Polypropylene	0.250"	0.115	0.171
Polyethylene	0.125"	0.146	0.190
Polyethylene	0.250"	0.115	0.167

TABLE III

TOTAL PACK COST

ITEM SIZE-10"x10"x10" ITEM FRAGILITY (Gs)	MATERIAL	MAXIMUM ORDER COST($)-CUSHIONING PLUS CONTAINER[1] STATIC STRESS (psi) .08	.10	.15	.20	.25	.30	.35	.40	.42
150	Polypropylene (1/8")	0.74	0.63	0.63	0.63	0.63	0.74	0.74	0.74	0.74
	Polypropylene (1/4")	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69
	Polyethylene (1/8")	0.64	0.64	0.64	0.64	0.76	0.76	0.76	0.76	0.76
	Polyethylene (1/4")	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69
100	Polypropylene (1/4")	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87
	Polyethylene (1/4")		1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08
75	Polypropylene (1/4")			1.08	1.08	1.08	1.08	1.08	1.08	1.08
	Polyethylene (1/4")				1.30	1.30	1.30	1.30	1.30	1.30
		MINIMUM ORDER COST ($) - CUSHIONING PLUS CONTAINER[1]								
150	Polypropylene (1/8")	0.87	0.72	0.72	0.72	0.72	0.87	0.87	0.87	0.87
	Polypropylene (1/4")	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82
	Polyethylene (1/8")	0.72	0.72	0.72	0.72	0.86	0.86	0.86	0.86	0.86
	Polyethylene (1/4")	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81
100	Polypropylene (1/4")	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07
	Polyethylene (1/4")		1.34	1.34	1.34	1.34	1.34	1.34	1.34	1.34
75	Polypropylene (1/4")			1.36	1.36	1.36	1.36	1.36	1.36	1.36
	Polyethylene (1/4")				1.64	1.64	1.64	1.64	1.64	1.64

[1] Container size varied from 10-3/4" x 10-3/4" x 10-3/4" to 12-1/2" x 12-1/2" x 12-1/2" and the container cost varied from $0.399 to $0.536.

At 0.42 psi and a fragility level of 75 Gs, Polypropylene requires four plies of 1/4" material (Figure 1). Twenty-five percent of 1 inch equals 1/4" which is the additional amount of material required to offset creep. This extra 1/4" should be added to all six faces which will increase the pack cost by $0.17. This increase in pack cost from $1.08 (Table III) to $1.25 is about 16%.

The Polyethylene requires five plies of 1/4" material to protect the item to the same fragility level and a static loading of 0.42 psi. Using the same analysis as above, it can be shown that the pack cost will be increased by $0.17 which is 13% of its original cost of $1.30 (Table III).

Since the weight of a pack is also a consideration with regard to cost and handling, an analysis was accomplished of the weight differences of the packs used in the previous cost analysis of creep effects. The weight differences, disregarding the extra material added to allow for creep, was noticeable. The Polypropylene pack weighed 2.08 lbs and the Polyethylene pack weighed 2.69 lbs; that is, the Polyethylene Foam pack weighed about 29% more than the Polypropylene pack. These weights disregard the item weight.

CONCLUSIONS

Based on data collected during this study, it appears that no cost savings can be realized by substituting Polyethylene for Polypropylene in currently used pack designs. It is believed that Polyethylene could be used in place of Polypropylene at a slightly reduced cost effectiveness for items having fragilities of 150 Gs or greater.

RECOMMENDATIONS

It is recommended that:

a. Polyethylene wrap materials not be substituted for Polypropylene wrap materials in current pack designs.

b. Polyethylene be considered as alternative to Polypropylene when material costs are equivalent in new pack designs.

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The objective of this study was to evaluate the static and dynamic cushioning properties of polyethylene wrap material in relation to polypropylene wrap material and to determine the relative cost effectiveness of the two materials in package designs.

Peak acceleration (Gs) versus Static Stress curves and "Creep" characteristics were developed for both materials. Using these data and a mathematical model, a cost analysis was accomplished.

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polyethylene for polypropylene. However, polyethylene should be considered as an alternative to polypropylene in new pack designs when item fragility and static bearing stress considerations result in equivalent material costs.